

# Preparation of an Environment Friendly Adhesive Mortar

Li Hao<sup>1 a</sup>, Li Peixin<sup>2</sup>, Fu Linlin<sup>3</sup>, Mu Yan<sup>2</sup>, Fu Yingli<sup>2</sup>, Liang Xuesong<sup>2</sup>, Liu Shaojie<sup>2</sup>, Zhao Feng-qing<sup>1 2 b</sup>

1. College of Chemical & Pharmaceutical Engineering, Hebei University of Science & Technology, Shijiazhuang 050018, PR China

2. Hebei Building Materials Industry Design and Research Institute, Shijiazhuang 050018, PR China

3. Hebei Huafei Technology Consulting Co., Ltd.

<sup>a</sup>lhzm2006@163.com; <sup>b</sup>zhaofq3366@126.com

## Abstract

In this paper, a new polymer-modified adhesive mortar is prepared using the fine iron tailings, eco-cement, re-dispersible latex powder, additives and water. In the preparation, the fine iron tailings are used to replace the river sand as the mortar aggregate. The Orthogonal experiment is designed to determine the optimal process conditions. The obtained results are as follows: the cement-sand ratio is 1:2.5, polymer-cement ratio is 4 %, the aggregate modulus is 0.81, and water reducing agent is 0.5 % (cement based). The properties of obtained polymer-modified adhesive mortar in the optimal process conditions conform to JC/T 547-2005 (The China Professional Standard: Ceramic Tile Adhesive).

## Keywords

*Eco-cement; Iron Tailings; Aggregate; Adhesive Mortar*

## Introduction

For reduction of energy consumption and environment pollution, it has been very important to treat and utilize the iron tailings. In the past, landfill was the main treatment method for these wastes. However, producing building material has got more and more attentions these years. Some products have been produced from tailings, such as bricks, concrete, cement and ready-mixed mortar, etc. [1-10]

Preparation of polymer-modified mortar also was reported. Mum et al [11] studied the influence of fine tailings with size of 10-69  $\mu\text{m}$  on polymer-modified mortar properties. They found that replacement of ground calcium carbonate (GC) with fine tailings (FT) can prolong the working life of polyester mortars. From the vantage point of the strength development of the polyester mortars with FT, it is recommended that the replacement of GC with FT should be controlled at

50% or less. Choi et al [12] developed a mortar with acceptable properties using tailings from tungsten mine waste with 10-30  $\mu\text{m}$  of average particle size. The volume of tungsten waste is suggested up to 10% by mass.

Recently, we developed a new type of environmental friendly polymer-modified waterproof mortar by eco-cement, tailings, quartz sand and additives. In the preparation, the quartz sand was partly replaced with tailings. Good properties of this mortar have been found [13]. In this paper, we will produce a new ceramic tile cementing mortar by iron tailings mixing with cement, re-dispersible latex powder etc. In this method, the river sand is completely replaced by fine iron tailings.

## Experimental

### Materials

Eco-cement is obtained from our previous work [7, 14]. The re-dispersible emulsion powders are commercial EVA provided by the Wacker co.. Its glass transition temperature is -2  $^{\circ}\text{C}$ , and minimum forming film temperature is 0  $^{\circ}\text{C}$ . The powders can form an opaque film which had a certain degree of flexibility. Fine tailings (80  $\mu\text{m}$  sieve residue, 17%) supplied by Cheng De Tong Xing Mining Co., Ltd. have similar compositions with river sand. The compositions of tailings and river sand are summarized in Table 1. In order to improve the performance of the adhesive mortar, de-foaming agent (tributyl phosphate) and water reducing agent (naphthalene sulphonate) produced by Hebei Admixtures Factory are used. The used water is the tap-water.

TABLE 1 COMPOSITION OF TAILINGS AND RIVER SAND

Component	SiO <sub>2</sub>	Al <sub>2</sub> O <sub>3</sub>	Fe <sub>2</sub> O <sub>3</sub>	CaO	MgO	SO <sub>3</sub>	Loss
Tailings	55.62	11.42	11.03	13.03	9.09	1.77	2.17
Sand	73.13	12.50	6.20	1.02	2.10	-	2.81

### Methods

The eco-cement, iron tailings, re-dispersible emulsion powders, additives and water are mixed to form adhesive mortar. The test specimens (40 mm×40 mm×2 mm) are made in the mould and cured for 24 h, firstly. Then, they are kept in the conditions, 20 ± 2 °C and 90 ± 5% relative humidity (RH) for the desired period. The mechanical strength, consistency and adhesive test are done according to GB/T 1767 1-1999, JGJ70-90 and JC/T 547-2005 (Adhesives for ceramic wall and floor tile), respectively.

All the values used in this paper are the average of four separate tests. SEM test is carried out using HITACHI S-570 Scanning Electron Microscope.

The Orthogonal array experiments are done to obtain optimal proportion of the mortar. Based on our exploratory experiments and other reports, three main factors, the cement/tailings ratio (A), polymer/cement ratio (B) and aggregate modulus (C) are selected for proportion optimization. Based on our exploratory experiments, EVA is selected as the polymer. The defoaming agent and water reducer are 0.2 wt. % and 0.5 wt. %, respectively (based on the amount of cementing material). Effects of various factors on mortar properties (mainly the 28d's adhesive strength) are examined through the designed orthogonal experiments. Based on the results, the verification experiment is arranged and the optimal mortar proportion is determined. The factors and levels of the orthogonal experiment are shown in Table 2.

TABLE 2 FACTORS AND LEVERS OF ORTHOGONAL EXPERIMENT

Levels	Factors		
	Cement/tailings ratio (A)	polymer/cement ratio (B)	Aggregate modulus (C)
1	1:1.5	2%	0.81
2	1:2	4%	1.56
3	1:2.5	6%	1.96

### Results and Discussion

#### Analysis of Orthogonal Experiment

In this paper, the 28d's original bond strength (bond strength 1) is selected as the main indexes for the

physical strength and toughness of mortar. The experimental results are summarized in Table 3.

TABLE 3 EXPERIMENTAL PROGRAM AND RESULTS OF 28D'S BOND STRENGTH

Experiment number	Factors			Results /MPa
	A	B	C	
1	1	1	1	0.63
2	1	2	2	0.50
3	1	3	3	0.50
4	2	1	2	0.50
5	2	2	3	0.73
6	2	3	1	0.36
7	3	1	3	0.93
8	3	2	1	0.61
9	3	3	2	0.61

For intuitive analysis, we use the original 28d's bond strength, 28d's bond strength after immersion in water and 28d's bond strength after 25 freeze-thaw cycles as the objective respectively. The effective curves are shown in Figure1.

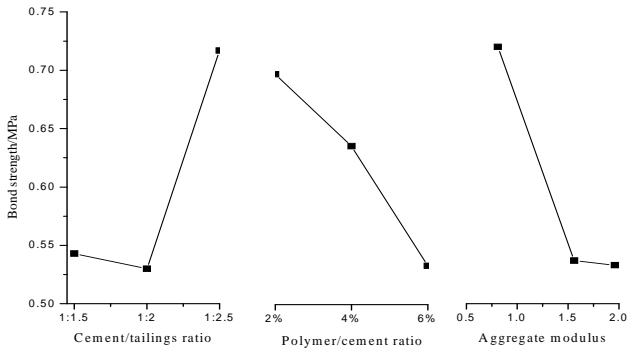


FIG. 1 THE EFFECTIVE CURVES FOR ORIGINAL 28D'S BOND STRENGTH

The effective curves show that the polymer-cement ratio and cement-tailings ratio have significant effect on the 28d's bond strength. The influence of aggregate modulus is relatively insignificant. This may be due to that the addition of polymer delays the dry time of mortar. This effect makes the cement hydration more sufficient. Another reason may be that the polymer can reduce the micro-cracks caused by dry-shrinkage and plastic-shrinkage of the tile adhesive mortar. Meanwhile, the polymer film gives a bridge connection between the contact interface of tiles and mortar, which can heal the cracks, to improve the bond strength. The influence of aggregate modulus is less than the other two factors. This indicates that fine tailings can be used as the substitute of river sand. The reason may be that they have similar chemical compositions. Considering the 28d's bond strength value, the optimized result is A<sub>3</sub>B<sub>2</sub>C<sub>1</sub>, i.e. polymer-

cement ratio 4 wt%, cement–tailings ratio 1:2.5 and aggregate modulus 0.81.

### Validation Test

The validation test is done based on the optimized result A<sub>3</sub>B<sub>2</sub>C<sub>1</sub> in order to further improve properties of the mortar. The results are summarized in Table 4. It can be found that all the specifications of the mortar produced by the validation test meet the requirements of JC/T 547-2005 (Adhesives for ceramic wall and floor tile). Good properties of mortar prepared using fine tailings as aggregate may be due to that fine tailings have similar compositions with river sand. The result illustrates that the optimized result is reliable.

TABLE 4 RESULTS OF THE VALIDATION TEST

NO.	Specifications	JC/T 547-2005	Work
1	Original bond strength /MPa	≥0.50	0.95
2	Bond strength after immersion in water 20 days /MPa	≥0.50	1.08
3	Bond strength after thermal aging cycle(70±2 oC, 14 days)/MPa	≥0.50	0.73
4	Bond strength after freeze–thaw cycles(-15~20 oC, 25 times)/MPa	≥0.50	0.62
5	Bond strength after 20 minutes dry set/MPa	≥0.50	0.81

### Microstructure

To study internal morphology of the mortar, the SEM analysis of ordinary mortar and polymer-modified mortar is done. The results are shown in Figs.2, 3 and 4. It can be seen from Figs. 2-1 and 3-1 that the morphology of ordinary cement mortar is multiphase aggregate. There are large numbers of pores with less connection in the structure. In addition, the gap is large in the interfacial transition zone of cement-aggregate.

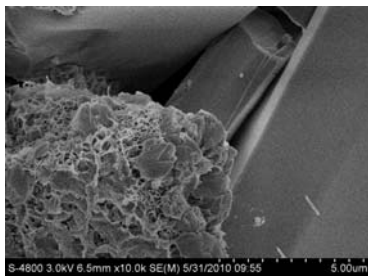


FIG. 2-1 SEM PHOTOGRAPH OF ORDINARY TAILINGS CEMENT MORATR

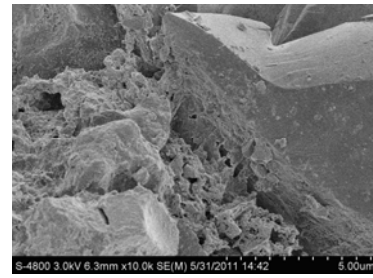


FIG. 2-2 SEM PHOTOGRAPH OF POLYMER-MODIFIED MORATR



FIG. 3-1 THE INTERFACE OF ORDINARY TAILINGS CEMENT MORTAR

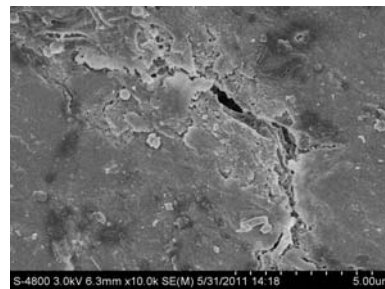


FIG. 3-2 THE INTERFACE OF POLYMER-MODIFIED TAILINGS MORTAR

Fig.2-2 and 3-2 are the morphology of polymer-modified mortar. From the two figures, it can be clearly found that the microstructure changes significantly compared with ordinary mortar. The Fig.2-2 shows that pores are filled up by many membrane-like substances and bonded together. It can be seen from Fig. 3-2 some of the membrane-like substances are across the pores like a bridge. The gap becomes smaller through these bridging and filling effects. The structure of polymer-modified mortar is further analysed. The results are shown in Fig. 4.

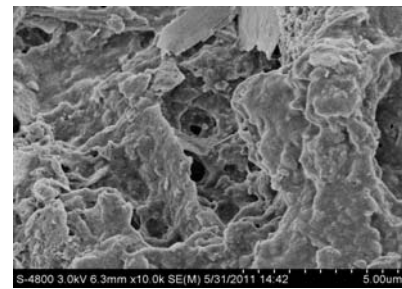


FIG. 4-1 MORPHOLOGY OF POLYMER IN POLYMER-MODIFIED TAILINGS MORTAR

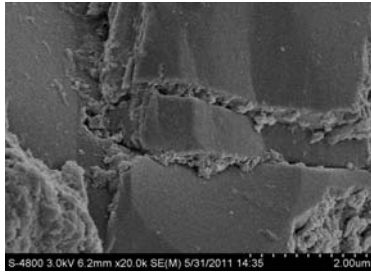


FIG. 4-2 MORPHOLOGY OF POLYMER BETWEEN AGGREGATES IN POLYMER-MODIFIED TAILINGS MORTAR

It can be seen that the polymer forms a film and constitute a part of the whole wall from the Fig.4-1. The film can play an important role in sealing the high porosity of the adhesive layer. Meanwhile the polymer films are intertwined to form a space network structure. Besides, the polymer film has a self-stretch mechanism, and the tensile stress will be produced through an internal force when subjected to external tension. This internal force can make the adhesive mortar as a whole to improve its cohesive strength. Fig.4-2 shows that polymer powders accumulate to form the film in the contact surface of aggregates. So the gaps are sealed in the contact surface and the bonding between the aggregates becomes more dense and firm. When subjected to external force, the emergence of micro-cracks will be prevented due to the flexibility and elasticity of the polymer film. The network formed by intertwined polymer film can prevent the merger of micro-cracks and improve the overall cohesion. Therefore, the added polymer can improve failure stress and strain of the adhesive mortar, and enhance its bonding strength.

## Conclusions

An environment friendly adhesive mortar is prepared using the eco-cement, iron tailings and re-dispersible emulsion powder of EVA. In the process, the common aggregates of river sand are completely replaced by fine iron tailings. The Orthogonal experimental results show that polymer-cement ratio and cement-tailings ratio are the significant factors to the performance of adhesive mortar. The influence of aggregate modulus is insignificant. The optimized result is cement-tailings ratio 1:2.5, polymer-cement ratio 4%, aggregate modulus 0.81 and water reducer 0.5% (based on the weight of cement). The performance of the bond mortar can reach the Standard of Adhesives for Ceramic Wall and Floor Tile. The mortar uses tailings as aggregate without decreasing the adhesive strength. It can reduce the cost, resource consumption and

tailings discharge, in line with the requirements of green production.

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